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STANFORD RESEARCH INSTITUTE

STANFORD, CALIFORNIA

October 1951

AD-A995211

Interim Report - Part II

HE TESTS - OPERATION JANGLE
Project 1(9)

by

E. B. Doll

Stanford Research Institute Project 424, WALRUS
Contract DA-49-129-Eng-119

Prepared for

Office of the Chief of Engineers
Washington D. C.

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DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON

EN~EB

26 November 1951

SUBJECT: Interim Report on Project 1(9) - High Explosive Tests - Operation JANGLE

TO: Director, Program One
Office of the Director Effects Tests
Technical Operations Squadron (Prov.)
P. O. Box 1349
Las Vegas, Nevada

1. Transmitted herewith Interim Report - Part II on Project 1(9) - High Explosive Tests - Operation JANGLE, dated October 1951, prepared by Stanford Research Institute under contract with the Office, Chief of Engineers. This document is classified SECRET.

2. The inclosed report contains an estimate of anticipated values of similar instrumentation for the "U" and "S" nuclear tests of Operation JANGLE. Issuance of this report has been expedited for the purpose of making such data available for planning purposes.

3. This report contains information affecting the national defense of the United States within the meaning of the Espionage Act, 50 U.S.C., 31 and 32, as amended. The transmission or the revelation of the contents in any manner to an unauthorized person is prohibited by law.

FOR THE CHIEF OF ENGINEERS:

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October 18, 1951

STANFORD RESEARCH INSTITUTE

Interim Report - Part II

HE TESTS - OPERATION JANGLE

I Introduction

The purpose of this report is to utilize the results of the HE Tests of Operation JANGLE (Project 1(9)) to estimate the anticipated similar results for the "U" and "S" one kiloton nuclear tests of Operation JANGLE.

The HE Tests of Operation JANGLE are reported in a Stanford Research Institute Interim Report of October 1951, classified CONFIDENTIAL. For reference purposes the CONFIDENTIAL Interim Report will be referred to as Part I, and it is assumed that the interested reader has it available.

In this report (Part II) no attempt is made to differentiate between the fundamental characteristics of HE (TNT) and nuclear explosions. In fact, the discussion herein assumes that a 1 KT nuclear explosion will release mechanical energy equivalent to 1 KT of TNT and will produce physical effects equivalent to those which would be produced by 1 KT of TNT. It would be more proper to state that this report utilizes the results of 2560 pound and 40,000 pound TNT explosions to estimate similar results for scaled experiments using 1,000 tons of TNT.

II Description of Tests

The tests under consideration may be described as follows:

	Pounds of TNT		Depth of Charge		
Test	W	$W^{1/3}$	ft	λ_c	Date
HE-1	2.56×10^3	13.8	1.9	0.135	August 25, 1951
HE-2	40×10^3	34.2	4.7	0.135	September 3, 1951
HE-4	2.56×10^3	13.8	-1.9	-0.135	September 9, 1951
U	2000×10^3	126	17	0.135	Future
S	2000×10^3	126	Surface		Future

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HE-1, HE-2 and U are scaled experiments and HE-4 and S are scaled experiments. The scale ratios are as follows:

Tests	Scale Ratio
U : HE-2	3.68
U : HE-1	9.2
HE-2 : HE-2	2.5
S : HE-4	9.2

For the application of model laws to scaled experiments it is assumed that the environment of the experiment (the air and earth) is either homogeneous or is described by dimensions related by the appropriate scale factor. In this case it is assumed that the air and earth are both homogeneous to the dimensions required for each experiment. In the case of the air this is a valid assumption. For the earth this may not be the case. It is known that the sub-surface characteristics have local variations throughout the test area (see Part I). It is also believed that there is a rather marked change in seismic velocity at a depth of 100 - 200 feet, which is shallow enough to affect 1 KT tests while possibly not producing pronounced effects on the smaller tests. In any event, a homogeneous earth has been assumed for the application of the normal model laws, with the test site and gage line of HE-2 used as the reference.

III Earth Acceleration

Examination of the earth acceleration records (Part I - Appendix) shows pronounced secondary effects which can be ascribed to the air-blast pressure pushing on the ground surface above the ground location. These induced air-blast effects were generally of short duration compared to the remainder of the accelerometer records. In particular, it would appear that for charges in excess of a few thousand pounds the duration of these effects is dependent on the characteristics of the earth rather than on the charge size. As a consequence, for large charges these locally induced effects are probably not of major military importance. For HE-1 and HE-2 the amplitudes of these short duration air-blast induced effects did not scale, while the remainder of the phenomena did scale.

For the purposes of this discussion the locally induced air-blast effects have been removed from the acceleration records, and consideration is given only to the relatively low frequency acceleration components produced by the fundamental explosive forces operating through the earth alone. The importance of the induced air-blast effects in the design of instrumentation is recognized, and further discussion of these phenomena will be given later.

Figure 1 shows the wave-forms estimated for the earth acceleration on the U test, neglecting the air-blast induced effects. These curves have been prepared by the application of the normal model laws to the results of HE-1 and HE-2. The horizontal records for HE-1 and HE-2 were quite consistent and a single representative wave form appears appropriate. There were some relatively strong later arrival accelerations, but these phenomena appeared not to follow any systematic pattern regarding either wave-form or amplitude.

The curves of Figures 2 and 3 show the expected peak amplitudes of the horizontal earth acceleration as functions of λ and R for Test U. For Test S these peak accelerations should be reduced by about 25 per cent, although the wave-form of Figure 1 should still apply. Estimates for Test S are based on HE-4, where the air-blast induced effects were not excessive on the horizontal earth acceleration.

The vertical earth acceleration records are more complex than the horizontal, as shown in Figure 1. Furthermore, the local air-blast effects are more pronounced on the vertical records, and the true low frequency character is difficult to ascertain. It appears that for small values of λ the initial positive vertical peak is the maximum peak, while for larger λ values the first negative peak and the second positive peak are nearly equal and considerably greater than the first positive peak. For low λ values the low frequency peak vertical acceleration is estimated to be about one-fifth the peak horizontal acceleration shown in Figures 2 and 3. Direct scaling applied to HE-2 would show a flattening of the vertical acceleration graph in the region λ 10 to λ 12, with the peak vertical accelerations becoming equal to the horizontal accelerations in this region and exceeding them at larger distances.

However, a study of the HE-1 and HE-2 results shows this flattening of the vertical acceleration versus distance curve to occur at a distance of about 500 feet for each test, indicating that this effect does not scale. If this effect truly occurs at 500 feet this corresponds to a λ value of about four for a 1 KT test. This leads to the distinct possibility that the vertical component can exceed the horizontal component at distances beyond about λ 5 or λ 6 for a 1 KT test. It appears that there is either insufficient data or insufficient analysis, or both, to estimate the vertical earth acceleration for 1 KT tests at this time. It is generally believed that the horizontal component of acceleration is of major importance in producing military damage, and this component can be estimated with some degree of assurance.

It is to be noted that this report has considered the maximum low frequency peak of earth acceleration, as compared to Part I

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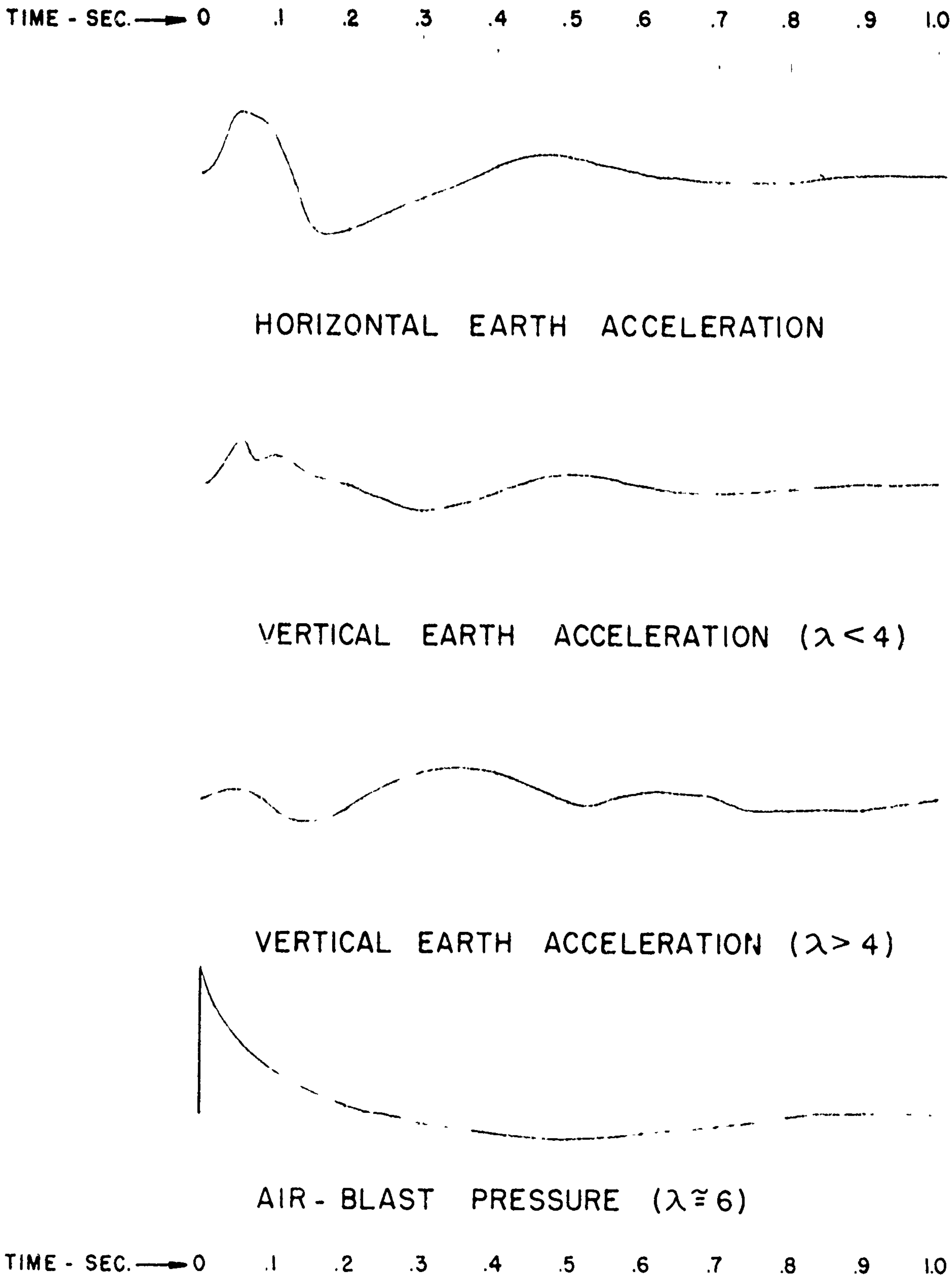

FIGURE I

ESTIMATED WAVE - FORMS

TEST U AND TEST S (1KT)

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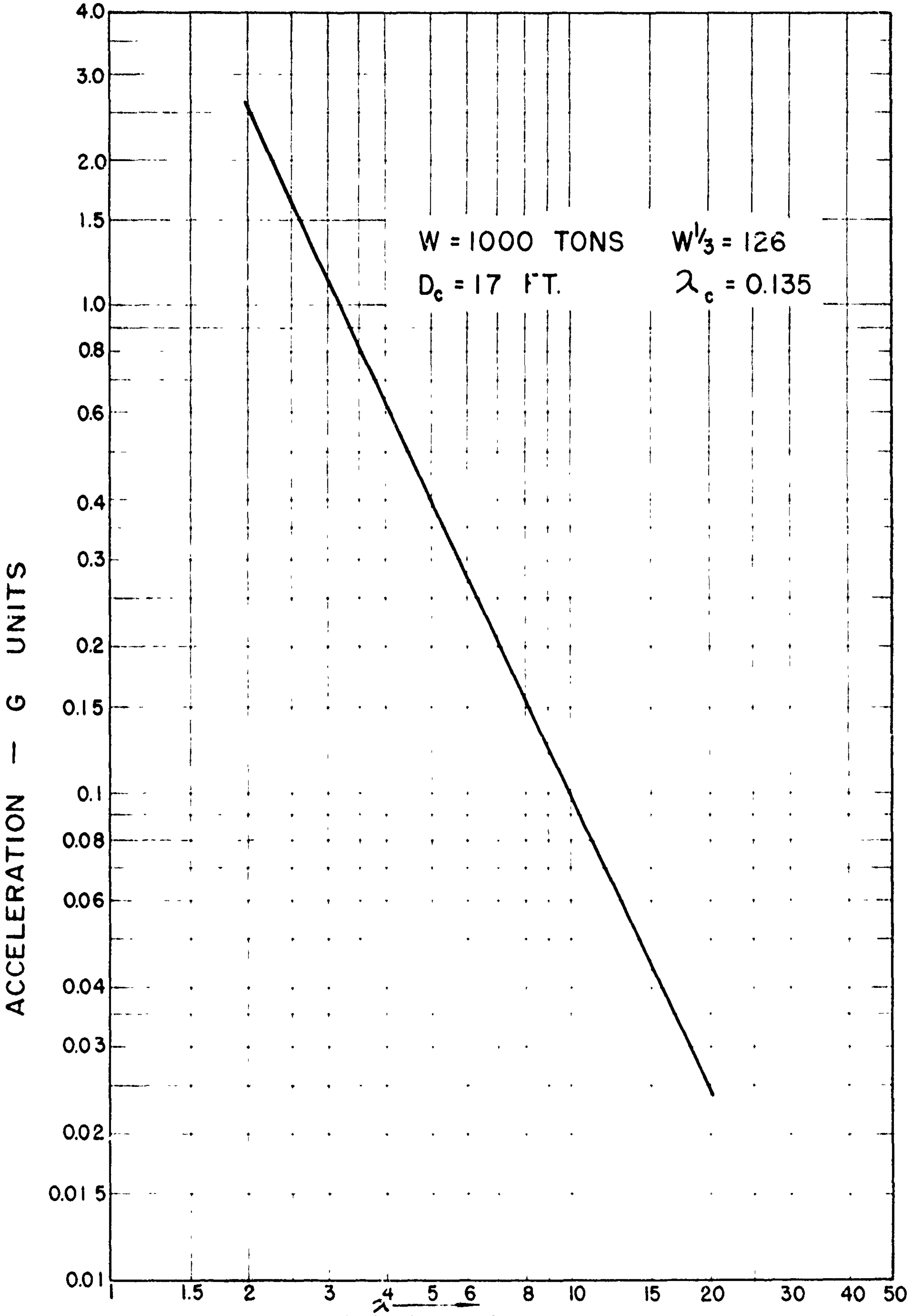


FIGURE 2
PEAK HORIZONTAL EARTH ACCELERATION
(less induced air-blast effect)
TEST U

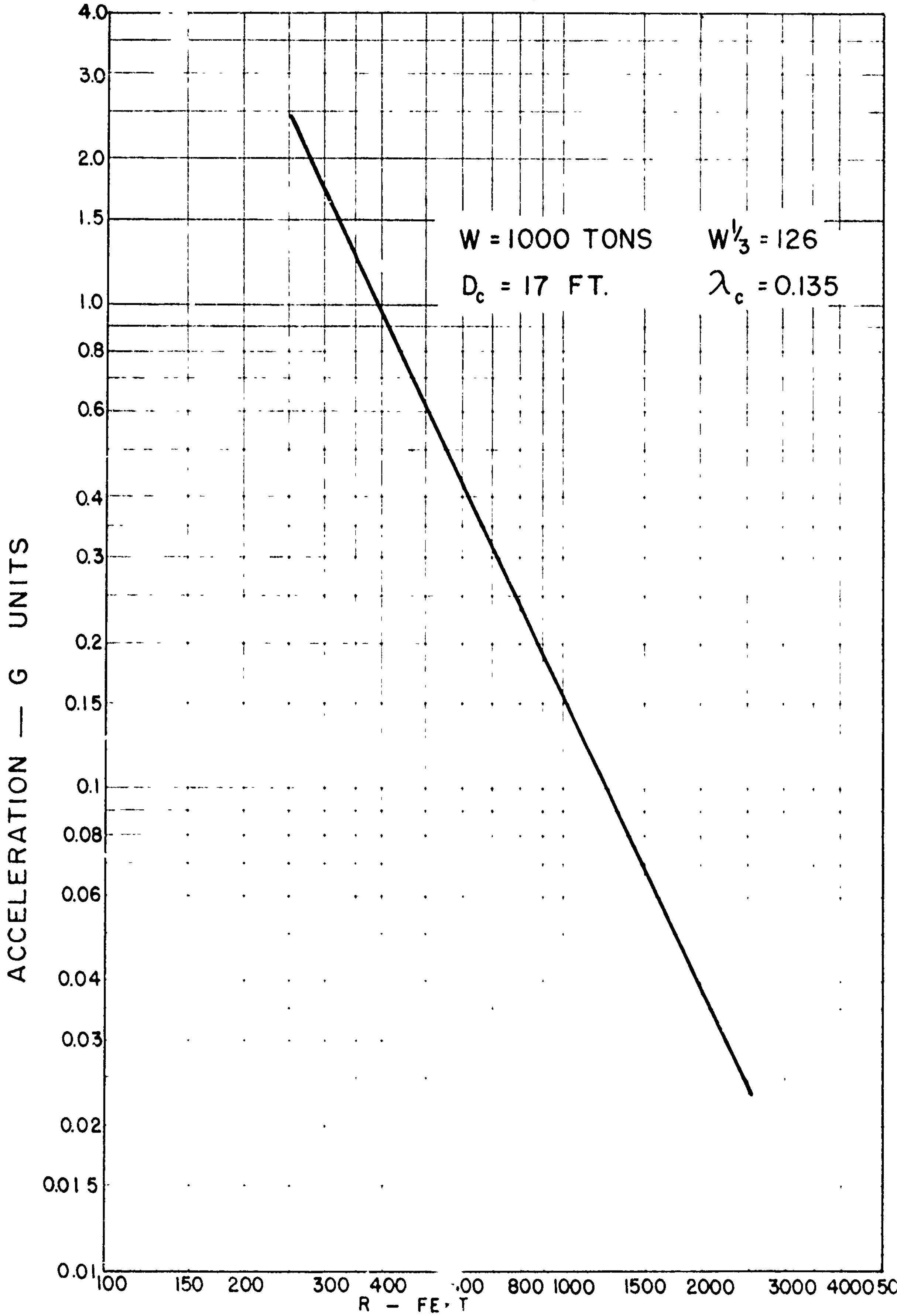


FIGURE 3
PEAK HORIZONTAL EAR H ACCELERATION
(less induced air blast effect)
TEST

where the first peaks were considered. This makes little difference in the horizontal component, but for the vertical component the maximum low frequency peaks were generally several times greater than the first peaks at λ 6 and larger.

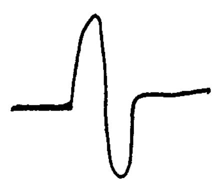
On Test HE-4 the local air-blast induced effects completely dominated the pertinent vertical earth-acceleration records. It is impractical to estimate the low frequency vertical earth acceleration for Test S, although there is some reason to believe that the wave-forms and amplitudes may differ quite markedly from those estimated for Test U. In general, the amplitudes are expected to be lower.

The earth-acceleration measurements reported were obtained at a gage depth of five feet for all HE tests. A few measurements at a depth of 17 feet on HE-2 showed no major difference in either wave-form or amplitude. Except for local induced air-blast effects it is believed that the earth accelerations will not be greatly different at the principal gage depths of five and ten feet planned for the two nuclear tests.

IV <u>Local Air-Blast Induced Effects on Earth Acceleration</u>

A comparison of the vertical earth acceleration records from HE-1 and HE-2 shows that the local air-blast induced acceleration peaks were about the same for the two tests at equal λ distances. If anything, there was a slight increase with charge size. From this it would appear that this phenomenon does not follow the simple acceleration model law, wherein for scaled experiments the peak acceleration is inversely proportional to charge diameter ($W^{1/3}$). Furthermore, the durations of the induced accelerations for HE-1 and HE-2 were of nearly the same value, again indicating a failure to scale.

Figure 4 shows the approximate wave-form of this phenomenon.



Period approx. 0.025 sec.

FIGURE 4

LOCAL AIR-BLAST INDUCED VERTICAL EARTH ACCELERATION

It is possible to visualize this phenomenon as resulting from the sharp front of the air-blast wave, and being relatively independent of the positive phase duration of the pressure wave as long as the duration is somewhat greater than the period of the induced acceleration. This period could be a function of the earth's characteristics and the gage depth. If this reasoning is correct it could lead to the conclusion that, for a fixed gage depth (in feet), the peak induced acceleration at a fixed λ distance is constant for all charge sizes above a certain minimum value, since the peak air-blast pressure for fixed λ values is independent of charge size for scaled experiments. Although this is probably of little military importance, it could have a profound effect upon the design of instrumentation, since these short duration peaks would have a greater amplitude relative to the low frequency earth accelerations for larger charges, with phasing dependent upon the seismic and air shock velocities.

On HE-1 and HE-2 these induced peaks of vertical earth acceleration had values ranging from 6 G at λ 2 to 2 G at λ 8. If these values remain constant for the scaled U test they are much greater than the estimated low frequency peaks. Based on a few HE-2 measurements at a depth of 17 feet it is estimated that this effect would be somewhat reduced at a gage depth of ten feet instead of five feet.

V <u>Air-Blast Pressure</u>

The HE-1 and HE-2 air-blast pressure records indicate good model law behavior. Hence it is expected that the model law can also be applied to HE-4 for air-blast pressure. One estimated air-blast pressure record (λ 6) is shown on Figure 1. This wave-form should apply to both the U and S tests, with the positive phase duration varying from about 0.2 second at λ 4 to 0.35 second at λ 15. Estimated peak air-blast pressures for U and S are shown on Figures 5 and 6.

VI <u>Earth Pressure</u>

As discussed in Part I, the earth-pressure measurements on the HE tests were made in shallow holes. No reasonable model law behavior could be established between HE-1 and HE-2 because of the limited measurements on HE-1. Two measurements at a gage depth of 17 feet on HE-2 (holes filled to the top with Aquagel solution) gave peak values about three times those obtained in the five-foot holes. No formal estimate is made of the earth pressure for the U and S tests. For instrumentation at a depth of ten feet on Test U peak earth-pressure values are estimated at twice those reported for HE-2 in Part I (for the same λ values of gage distance from ground zero).

It is worth noting that the local air-blast induced effects on the earth-pressure measurements (open holes) on HE-4 were most pronounced at fairly large λ values. This is perhaps due to the fact that the air-blast pressure is attenuated less rapidly with distance than is the earth pressure.

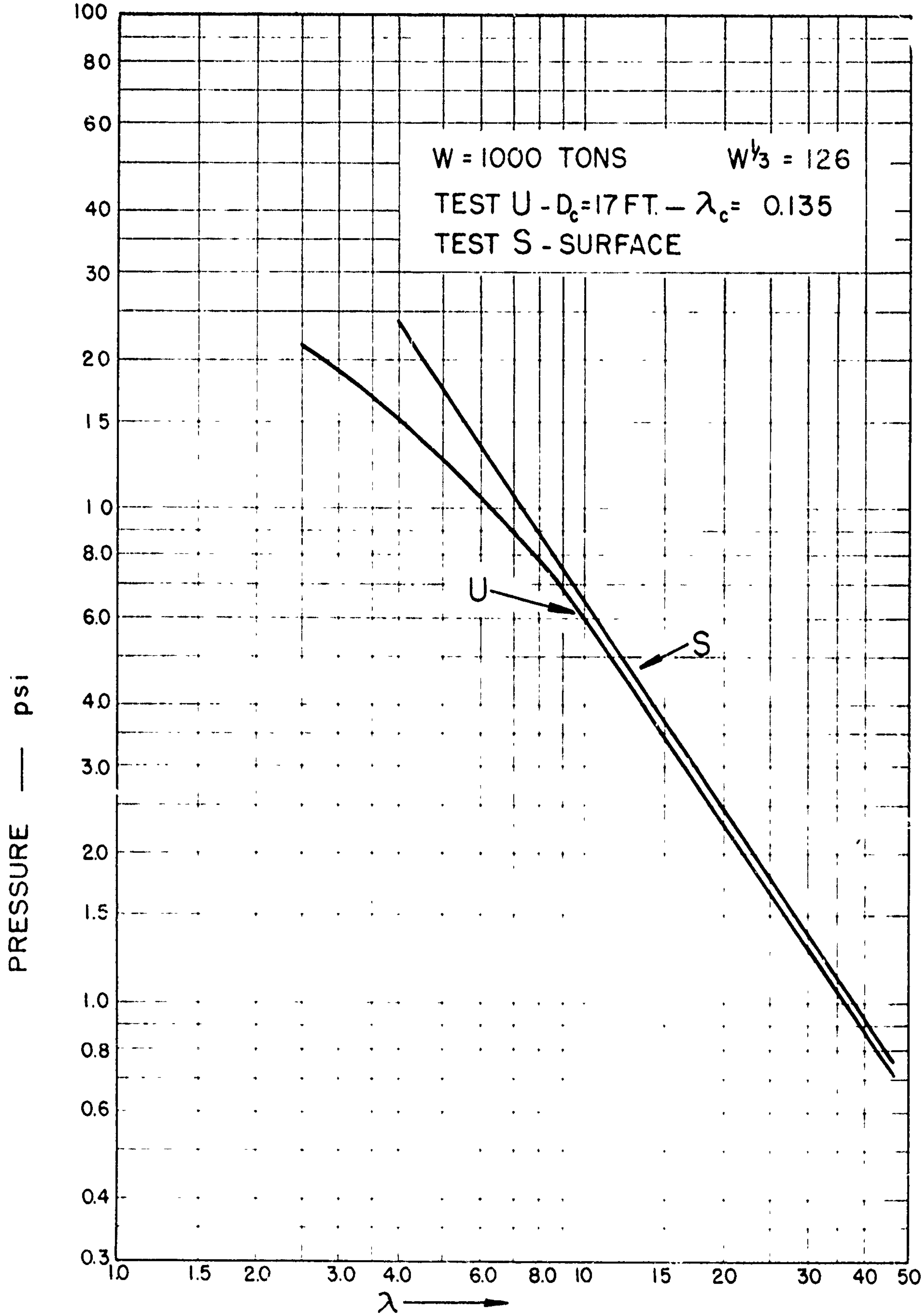


FIGURE 5

PEAK AIR – BLAST PRESSURE

TEST U AND TEST S

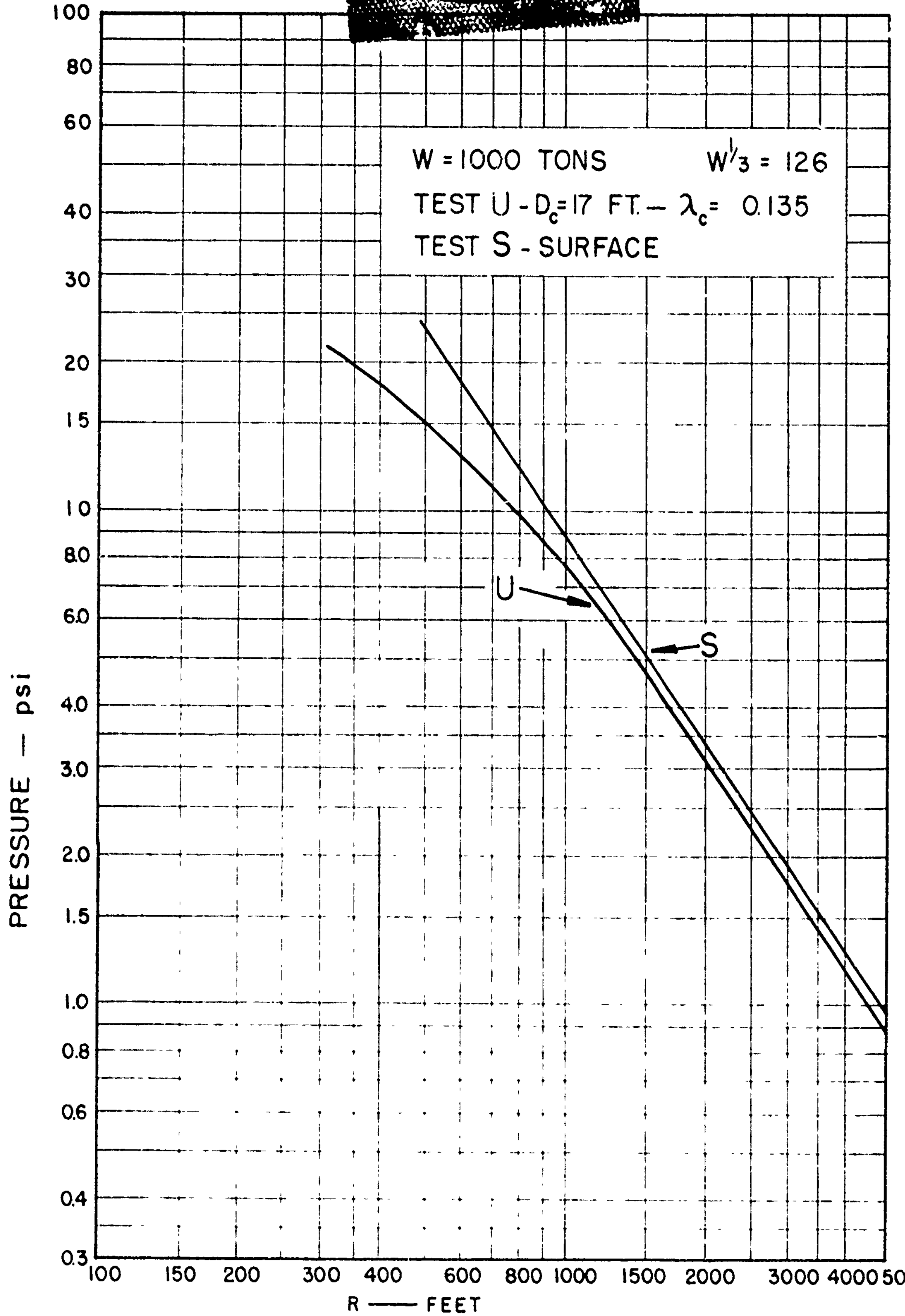


FIGURE 6

PEAK AIR – BLAST PRESSURE

TEST U AND TEST S